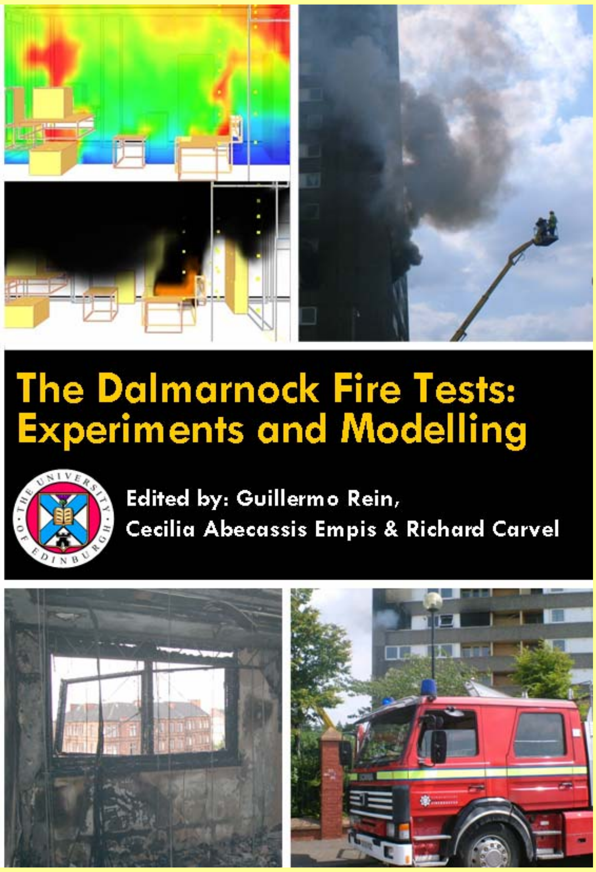
The Dalmarnock Fire Tests: Experiments and Modelling
Edited by G. Rein, C. Abecassis Empis and R. Carvel



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Preface: The Dalmarnock Fire Tests

By José L. Torero & Richard Carvel

Fire Safety Engineering

Fire Safety Engineering is a modern and exciting profession where state of the art tools are currently deployed for building design, industrial safety and forensic investigation. The scientific underpinnings of egress modelling were established in the 1960s. Modern understanding of fire dynamics is largely the product of two decades (1970s and 1980s) of remarkable scientific productivity. The 1990s were marked by the Cardington Tests and analysis that finally addressed a gap in the comprehensive development of a strategy for fire: structural behaviour. The scientific production during these forty years covered research from governments, academia and industry and set the framework for the development of modern engineering tools such as standard tests, computer models, etc. Furthermore, modern detection, suppression and fire proofing technologies spun-off from this scientific knowledge and are now incorporated into the built environment as standard practise. Over the years, numerous large scale tests have provided elements of validation for tools and technologies giving confidence to engineers. The result is a solid professional identity and a thriving industry that uses the developed knowledge and engineering tools to explore – with increasing frequency – practices that extend beyond prescription and embrace Performance Based Design.

Given the current state of the art, the vibrancy of the profession and existing data from numerous large scale tests, why are new large scale experiments like the Dalmarnock Tests important or, indeed, even necessary?

Why perform these tests?

The answer to this question is complex and requires the analysis of a broad range of issues fundamental to the profession. Such an analysis escapes the scope of this introduction, nevertheless a brief description of the motivation behind these tests is essential to put them in context and establish their importance.

While the profession of Fire Safety Engineering is apparently thriving, the academic activity that underpins it is dry. Investment in fire science has decreased consistently since the early 1990s and the flow of professionals that can rightfully be labelled ‘Fire Safety Engineers’ is considerably below the level of demand. This career is ‘off the radar’ for undergraduate students and funding agencies, thus we are risking loosing our recently acquired identity as a profession. There is therefore an urgent need to provide visibility to

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the profession at all levels, from the high school student, to the fire service and to the government official.

In the absence of Fire Safety Engineering graduates and the associated academic scientific output there will be no one suitably equipped to understand the complete process of developing a fire safety strategy. This is particularly true of the structural aspects of fire safety, highlighted especially by the events of September 11th, 2001, which generated significant interest from the structural engineering community on the behaviour of structures in fire. Nevertheless, the academic infrastructure to convert Structural and Civil Engineers into professionals equipped to create a comprehensive fire safety strategy is non existent. The reality is that fire is, by its very nature, a multidisciplinary field where contributions from other disciplines are not only welcomed but essential. Nevertheless, the development of a comprehensive strategy requires individuals equipped with a broad understanding of all aspects of the problem, thus professional leadership should remain with Fire Safety Engineers, underpinned by the applied science that is developed within the context of this safety objective.

Hence the first and foremost motivation for the Dalmarnock Fire Tests was one of generating visibility for the profession. We thus embarked on the mission of convincing the BBC to devote one of the episodes of their flagship documentary programme, Horizon, to the subject of Fire Safety Engineering. More than 3 years later the Horizon show: *"Skyscraper Fire Fighters"* aired on BBC2 in the UK on April 24th, 2007. The centrepiece of this documentary was the Dalmarnock Fire Tests.

The documentary was the main driver to conduct the tests and achieving visibility remained the key objective. Nevertheless, the Dalmarnock Fire Tests were also constructed to fill an essential scientific gap within current Fire Safety Engineering practices. As mentioned before, the engineering of fire safety is based on a multiplicity of tools that have evolved across four decades. Many of the initial formulations were based on large scale test observations, thus most of the large scale tests available were conducted in the 1970s and 80s and had as objective to understand the different processes or to validate simple engineering tools. Tools have evolved considerably since then and become more detailed and complex, nevertheless, compatible large scale validation data has not been generated at the required pace. This is true both in a quantitative and qualitative manner. Currently, we do not have enough test data to provide the information required. The implementation of Computational Fluid Dynamics (CFD) and Finite Element Modelling (FEM) for fire implies solving the equations involved to the centimetre resolution. Thus, validation data needs a similar resolution and has to cover as many variables as the models can provide output for. This type of data is very scarce in fire, therefore our tools have not received adequate validation. The design of the instrumentation for the Dalmarnock tests was done in strict accordance with the validation requirements for CFD and FEM models. Furthermore, an international blind (or *'a priori'*) round robin was organised to deliver model outputs before the test results were made public. Blind predictions are an essential component of the validation process as they test not only the assumptions of the model codes, but also the assumptions and practises of the modellers themselves.

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The Experiments

Three experiments were conducted. Two of them were conducted within identical independent flats to establish an estimate of repeatability. It is a common conception that fire experiments can differ enormously from each other, therefore many repeats are necessary to achieve validation data. Given the cost and complexity of large scale fire experiments, it is evident that the number of repeats that will establish statistical validity for the data will never be achieved. Therefore, an entirely different approach was followed here. The fuel layout for both experiments was defined to minimise variations between them. The main two processes that can lead to drastic differences are, first: the ignition of individual items before flashover and second: the windows breaking and falling out. The ignition issue was addressed by defining a robust ignition protocol for the first item and by placing the first burning item in close proximity to a large quantity of fuel arranged vertically on a bookshelf. This provided an ISO room corner test type of configuration where it was guaranteed that flashover will be attained soon after the ignition of the second item. The potential variability of the data was established by using considerably different ventilation for both tests. For the first test, only the doors to the ignition room were left open, while for the second test doors, windows and a large hole in one of the walls ensured free flow of air and smoke in and out of the room. The large hole served a double purpose of providing extra ventilation and allowing the camera crew direct access to the room. The differences between both experiments have been quantified indicating a small variance between the data. One of the experiments was allowed to progress beyond flashover and in this case the window was broken at a pre-specified time. The ceiling and walls of this compartment were instrumented to obtain a relevant pool of data for FEM model validation and the assessment of some novel construction materials. Thus, a detailed data set was produced together with an adequate estimate of its robustness. The Dalmarnock Fire Tests can therefore be used with confidence to assess several different aspects of fire modelling.

A comprehensive set of laboratory tests were conducted with the main combustible materials involved. The data bank was used partially for the round-robin study but mainly to assist *a posteriori* modelling of the event. The main objective here was to provide to designers a sense of the robustness of the fire modelling process. This raises the question of what is necessary to model a realistic fire to the level of accuracy required for design?

The third test carried out was a smoke filling experiment where a staircase was suddenly filled with smoke. The smoke was produced by a toluene pool fire confined to the alcove of the staircase. The door separating the alcove from the staircase was opened once the room was filled and smoke migration was monitored. This test was repeated several times.

A unique aspect of the Dalmarnock Fire Tests was the participation of Strathclyde Fire and Rescue Service. Fire Brigades are the essential constituency for Fire Safety Engineers. Nevertheless, while they have fully embraced fire technology, they have generally not incorporated engineering methods into fire fighting strategies. Construction practises are changing and modern constructive forms have the potential to drastically affect fire

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fighting. Current training practises do not emphasise enough the impact that modern engineering is having on the behaviour of buildings in fire. Nevertheless, in the near future fire fighters will be entering buildings that may behave in a very unusual manner. Raising awareness of the operational advantages of engineering tools among the fire service personnel was also a key objective of these tests.

In this regard, the target was to demonstrate the importance of having detailed information about the progression of the event. This information could be used for early automated response and to inform fire fighters during intervention. In Fire Test Two, the information was used to control ventilation with a view to controlling the flow of smoke and heat and thus providing a safer operations environment. As explained before, the first test was allowed to burn naturally while the second was fully ventilated in a controlled manner. It was demonstrated that in the period prior to flashover, the ventilated compartment had almost ambient temperatures and almost unaffected visibility. This was clearly not the case in the Test One compartment where the temperatures rose steadily and visibility was rapidly lost.

The high sensor density within the experimental compartments of the building, made it possible to obtain a detailed description of the progression of the fires. In combination with pre-run fire models, this permitted some level of forecasting. Nevertheless, the Fire Fighters were only mildly briefed on the objectives of the tests and not provided with any of the data available so that normal operation procedures could be followed. In the background, the data flow was monitored to discern when direct observation of data leads to information overload. The Dalmarnock Fire Tests showed that as the fire grows the data flow exceeds the assimilation capabilities of those in command and thus the wealth of information becomes useless. Contrasting the detailed knowledge of the environment, a series of before/after the event CFD models and recorded fire fighter operations has provided invaluable information. This information is currently being compared with fire fighter training practises within the context of a large multidisciplinary project called FireGrid.

FireGrid

The FireGrid project intends to provide a series of information based tools that will assist both building design and fire fighter intervention. Through the development of the documentary and the implementation of the tests, FireGrid evolved into the overarching theme of the entire activity. The goal of FireGrid is to create a tool that can provide a continuous flow of information that is digested by physical models and decision making algorithms to provide a reduced information pool that adequately describes and projects the development of a fire and its consequences on people and the structure. The Dalmarnock Fire Tests were used as a mechanism to establish what will be necessary for such tools to provide information that will be useful during intervention. It can be concluded that the tests strongly emphasised the importance of data management and reduction.

The successful development of such a tool requires all our knowledge of fire and the contributions of a number of other specialist fields (structural engineering, sensor

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development, digital communications, artificial intelligence, etc.). The integration of fire into a broader engineering community is again a mechanism to promote the field. Finally, but most important, it demonstrates the value of engineering in fire fighting.

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